Barium in Stony Meteorites

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Abstract. Concentrations of barium have been determined spectrographically in 95 stony meteorites. The distribution of the concentration of barium in the chondritic falls appears to be log-normal in shape with a median of 4.5 ppm. The concentrations in the chondritic finds indicate a tetramodal distribution that may have resulted from terrestrial contamination, but that also may have been present initially. The fact that the finds represent a strongly selected sample of generally hard and resistant meteorites leaves the second alternative open as a distinct possibility.

Introduction. Values for the concentration of barium in stony meteorites were obtained by *Von Englehardt* [1936]. The most recent values have been obtained by *Pinson et al.* [1953] using spectrochemical techniques and by *Hamaguchi et al.* [1957] using neutron activation. In this work barium has been determined in a suite of ninety-five stony meteorites consisting of forty-three chondritic falls, forty-five chondritic finds, two carbonaceous chondrites, and five achondrites. In Table 1 the results of this work are compared with the earlier results.

The specimens, spectrographic equipment, and analytical techniques used by *Moore and Brown* [1962] in their study of the distribution of manganese and titanium were used in the present work. The concentrations of barium were within the limit of sensitivity under the conditions used and were determined by means of the emission line at 4554.0 A.

The standard deviation from the mean in this work is estimated to be about 20 per cent. A major source of variation appears to be in the sampling.

Results. The concentrations of barium in the ninety-five stony meteorites are given in Table 2.

Figure 1 shows the frequency of occurrence versus the logarithm of the barium concentration for forty-three chondrite falls. The distribution appears to be log-normal in shape. The median is 4.5 ppm, the mode is 4 ppm, and the antilogarithm of the mean of the logarithm is 4.8 ppm.

Figure 2 shows the frequency of occurrence versus the logarithm of the barium concentration for forty-five chondrite finds. It is difficult to assess whether the apparent tetramodal distribution is real or occurs by chance. The problem immediately arises as to whether the high barium concentrations in the finds are the result of terrestrial contamination or were present originally. Although the first alternative seems the more probable, the fact that the finds represent a strongly selected sample of hard resistant meteorites leaves the second alternative open as a distinct possibility.

The importance of carefully selecting samples to minimize the possibility of terrestrial contamination is well illustrated by our analyses of the Holbrook chondrite. A description of the samples used and their barium contents is given in Table 3. This fall consisted of many individual stones ranging in size from minute grains to a 6.6-kg mass.

Some of the specimens were collected immediately after the fall; others were picked up as much as twenty years later. The histories of our particular samples are unknown. The large fluctuation in the barium concentrations obtained seems to indicate selective contamination. Whether the specimen of the Saratov chondrite (22 ppm Ba) has also had an opportunity to become contaminated is unknown.

In the absence of more data it seems reasonable to suspect that the high barium concentrations in the finds are the result of terrestrial contamination from the ground and that the best value for the concentration of barium in chondrites is about 4 ppm. This number is about

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TABLE 1. Barium in Stony Meteorites as Determined by *Von Englehardt* [1936], *Pinson et al.* [1953], and *Hamaguchi et al.* [1957]

Meteorite	Von E.	Pinson	Hamaguchi	This Paper
	Barium, ppm			
Chondrites				
L'Aigle	3–10	...	...	...
Knyahinya	1–3	...	...	5
Holbrook	3–10	9	4.0	26*
Erxleben	1–3	...	...	...
Chantonnay	1–3	...	...	...
Barbotan	1–3	...	...	...
Aviles	<1	...	...	...
Bjurböle	<1	8	...	5
Pultusk	...	7	...	3
Homestead	...	11	...	...
Ransom	...	7	...	28
Hayes Center	...	32	...	30
Waconda	...	7	...	...
Assun	...	8	...	...
Forest City	...	9	3.7	4
Hessle	...	7	...	...
Kernouve	...	6	...	...
Barratta	...	7	...	...
Mocs	...	6	...	5
Tennasilm	...	10	...	...
Monroe	...	5	...	...
Long Island	...	100	...	190
Beaver Creek	...	5	...	...
Lumpkin	...	6	...	...
Cangas de Onis	...	5	...	...
Estacado	...	6	...	...
Warrentown	...	5	...	...
Modoc	...	...	3.6	5
Richardton	...	...	3.2	4
Nuevo Laredo	...	...	46	...
Eucrites				
Stannern	48	...	...	...
Juvinas	10–30	...	...	...
Chladnites				
Johnstown	...	5	...	2.5
Carbonaceous Chondrites				
Orgueil	...	<1	...	...

* Mean of eight samples; barium values were very erratic.

TABLE 2. Barium Concentrations in Stony Meteorites

Meteorite	Barium, ppm
Ordinary chondrite falls	
Alexandrovsky	10
Alfianello	3
Allegan	4
Beardsley	5
Bjurböle	5
Chateau Renard	6
Colby, Wisconsin	4.5
Dhurmsala	6
Elenovka	5
Forest City	4
Holbrook	26*
Ichkala	4
Kesen	4
Knyahinya	5
Krasnoi-Ugol	5
Kuleschovka	3.5
Kunashak	4
Marion	3
Maziba	4
Mocs	6
Modoc	9
Mordvinovka	6.5
Mount Browne	4
Nanjemoy	13
New Concord	4
Nikolskoie	2
Ochansk (1)	5
Ochansk (2)	4
Olivenza	6
Olmedilla de Alarcon	5
Pantar	5
Parmallee	3.5
Pervomaisky	5
Pultusk	3
Richardton	4
Saint Michel	4
Saratov	22
Sautschenskoje	4
Stavropol	2.5
Tane	5
Uberaba	4
Weston	6
Yatoor	6
Zhovtnevyi	6
Ordinary chondrite finds	
Acme	120
Alamagordo	26
Arriba	53
Aurora	20
Beenham	34
Berdyansk	7
Brisco County	150
Cavour	4
Chuvashskie-Kissy	5
Colby, Kansas	170
Coldwater	10
Coolidge	32
Covert	115

TABLE 2. (Continued)

Meteorite	Barium, ppm
DeNova	115
Farley	290
Fayette County (Bluff)	3
Gladstone	17
Goodland	10
Harrisonville	7
Hayes Center	30
Hugoton	200
Kansas City	4
Kelly	165
Kingfisher	5
Ladder Creek	94
LaLande	210
Long Island	190
Marsland	3
McKinney	6
Melrose	155
Morland	5
Ness County (1894)	20
Orlovka	18
Otis	7
Petropavlovka	4
Plainview	10

TABLE 2. (Continued)

Meteorite	Barium, ppm
Potter	155
Ransom	28
Roy	72
Rush Creek	5
Seibert	125
Texline	13
Tryon	190
Tulia	120
Wilmot	82
Carbonaceous chondrites	
Felix	4
Murray County	4
Achondrites	
Cumberland Falls	14
Johnstown	2.5
Norton County	2
Shalka	4
Shaw	26

* Erratic results from different samples; mean of 8 samples.

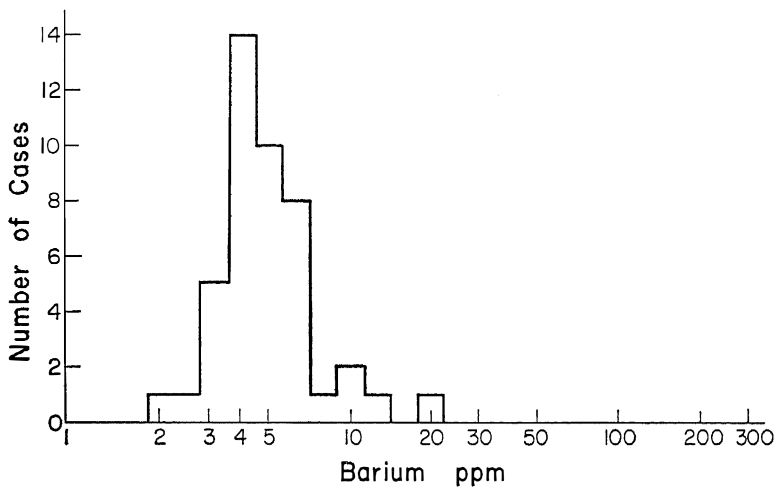

Fig. 1. Distribution of barium in chondritic falls.

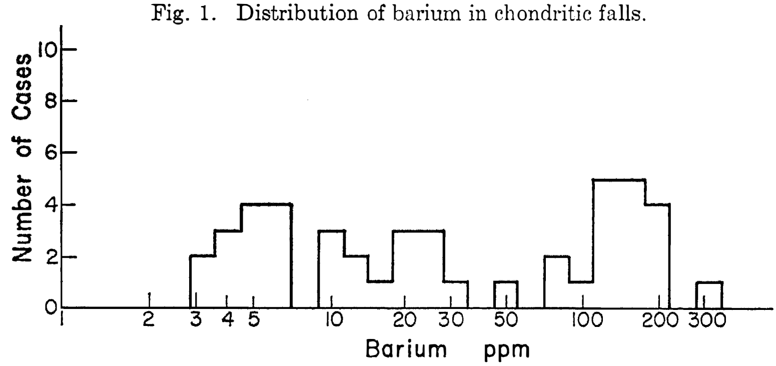

Fig. 2. Distribution of barium in chondritic finds.

TABLE 3. Concentrations of Barium in Eight Specimens of the Holbrook Chondrite

Sample	Barium, ppm
Several pea-sized fragments, 5 grams	28
Single fragment, 1 gram	9
Mainly black fusion crust, 1 gram	8
Single complete stone	74
Fine dust from complete sample	29
Nonmagnetic phase	24
Black crust, 0.5 gram	110
Small chips from all fragments, 3 grams	27
Median	26

one-half that given by *Pinson et al.* [1953] and very close to the more accurate determinations of *Hamaguchi et al.* [1957] which are, however, fewer in number. These data emphasize the importance of using falls instead of finds for all significant trace element work and also the importance of knowing the past history of recorded falls, since specimens are often on the ground for some time before they are collected.

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References

Hamaguchi, H., G. W. Reed, and A. Turkevich, Uranium and barium in stone meteorites, *Geochim. Cosmochim. Acta, 12,* 337–347, 1957.

Moore, C. B., and H. Brown, The distribution of manganese and titanium in stony meteorites, *Geochim. Cosmochim. Acta, 26,* 495–502, 1962.

Pinson, W. H., L. H. Ahrens, and M. L. Franck, The abundances of Li, Sc, Sr, Ba, and Zr in chondrites and some ultramafic rocks, *Geochim. Cosmochim. Acta, 4,* 251–260, 1953.

Von Englehardt, D., Die Geochemie des Barium, *Chem. Erde, 10,* 187–208, 1936.

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